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# **HAWAIIAN PLANTERS' RECORD**

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**Cover Picture**—Spraying a dense infestation of manienie with a multiple nozzle boom. This method of applying TCA has been used effectively on a number of plantations for eradication of the plant pest. Although single nozzles are more satisfactory for spot treatment, the multiple nozzle booms have stepped up man day performance in general use.

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# Controlling Manienie Grass with TCAA and STCA

By Q. H. Yuen and Robert C. Miller<sup>1</sup>

## SUMMARY

Research conducted by the Department of Chemistry has resulted in the development of a number of very effective sprays for controlling manienie grass, also known as Bermuda grass. One of these sprays is the multiple-hormone type, employing isopropyl ester of 2,4-D and either trichloroacetic acid or sodium trichloroacetate. Objectionable features of the ester may limit the areas in which this type of spray may be used.

Another spray consists of an aqueous solution of sodium trichloroacetate which, although not quite as effective as the multiple-hormone type, is still very potent. With proper dilution it may be used within cane lines.

With proper handling of formulations and a planned program of spraying, manienie can be completely controlled with comparatively few applications of TCA-2,4-D ester sprays. The program is to be based on the recovery and new growth in the treated area.

## INTRODUCTION

Research conducted during the past year has shown that trichloroacetic acid and its sodium salt are very effective herbicides for the control of manienie (Bermuda) grass, especially when used in conjunction with the proper form and quantity of 2,4-D acid. This grass is one of the chief weed pests infesting our plantations, particularly on drier areas. Control with herbicides other than those under study has not been too successful in the past. Our experiments were conducted to determine the proper combinations of these herbicides.

Mainland and local reports have indicated great promise for sodium trichloroacetate (STCA)<sup>2</sup> as a specific herbicide for controlling noxious perennial grasses. Results of our experiments in both greenhouse and field are in agreement with the results of others in that sodium trichloroacetate has a marked effect on the vigor and growth of manienie grass.

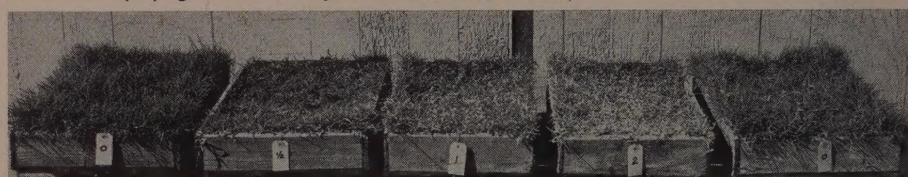
We have found that even as low a concentration as  $\frac{1}{2}$  pound of the 50 per cent grade of this herbicide in 100 gallons of spray solution, applied in sufficient gallonage to wet the foliage of young manie-

<sup>1</sup> Q. H. Yuen is associate chemist, Experiment Station, HSPA, and Robert C. Miller, former associate chemist.

<sup>2</sup> In weed control terminology on the mainland, the term "TCA" is used to indicate the acetates of trichloroacetic acid and the acid itself. In this paper we will use the abbreviation of each specific herbicide rather than the general term.



Figure 1. Effectiveness of 50 per cent grade sodium trichloroacetate in controlling growth of manienie grass (lawn variety). The flats were sprayed when the heavy mat was about one inch high. Photographed one month after spraying. Note size of growth and contrast in color.



	Lbs. 50% grade STCA per 100 gals. spray			
0	1/2	1	2	0
	Gallons per acre			
—	1000	1000	1000	—
	Lbs. 50% grade STCA per acre			
—	5	10	20	—

nie, has stopped the growth of this grass for a period of two months. With a concentration of two pounds (50 per cent grade) of this salt in 100 gallons of spray solution a distinct burn was produced. This experiment is illustrated in Figure 1.

Our experiments indicate that control of manienie grass to the point of complete kill with a single application of this herbicide is exceedingly difficult to

achieve. It appears that sodium trichloroacetate acts on the grass by checking growth. This reaction is illustrated in Figure 2. We have found that if growing conditions are favorable and the dosage applied is not high enough, the stunted plants, even with a dried and brown appearance, will after a period of two or three months regain their vigor and continue to produce new growth.

### INCORPORATING STCA IN CADE SPRAYS

A need was, therefore, indicated to learn more of this herbicide and to study means of improving its effectiveness. Experiments were conducted to study STCA-fortified CADE sprays, with or without the stock solution of activator

(SSA), in order to increase the effectiveness of sodium trichloroacetate.

Results appear to indicate that the addition of CADE, with or without activator, does not increase the effectiveness of STCA to any appreciable extent.

### TRICHLOROACETIC ACID (TCAA)

The hope was held that the parent compound of sodium trichloroacetate, namely, trichloroacetic acid, might be a more efficient herbicide. Moreover, the first commercial lots of sodium trichloroacetate that were available locally assayed only 50 per cent pure salt, and this fact could be expected to increase transportation costs somewhat. While the salt is soluble only in water, the acid is soluble in both water and Diesel oil. Therefore, experiments were conducted

to study the effect of trichloroacetic acid as a herbicide for manienie grass.

### TRICHLOROACETIC ACID IN WATER

An experiment, employing manienie grass growing in gallon cans, indicated that aqueous solutions of pure trichloroacetic acid were neither more nor less effective than the corresponding chemically equivalent quantities of sodium trichloroacetate applied in aqueous solutions. For example, 2.5, 5, 7.5, 10,

12.5, 15, 20, 30, or 40 pounds of pure trichloroacetic acid per 100 gallons of spray solution were found to correspond, respectively, to 5.7, 11.4, 17, 22.7, 28.4, 34, 45.4, 68.1, or 90.8 pounds of 50 per cent sodium trichloroacetate per 100 gallons of spray solution in effectiveness. In this phase of the experiments, as in all

others unless otherwise stated, a sufficient volume of spray solution was applied to thoroughly wet the foliage and partly wet the undergrowth.

Even the highest concentration of acid (40 pounds per 100 gallons) did not kill the grass in one application. New growth was developing at the end of two months.

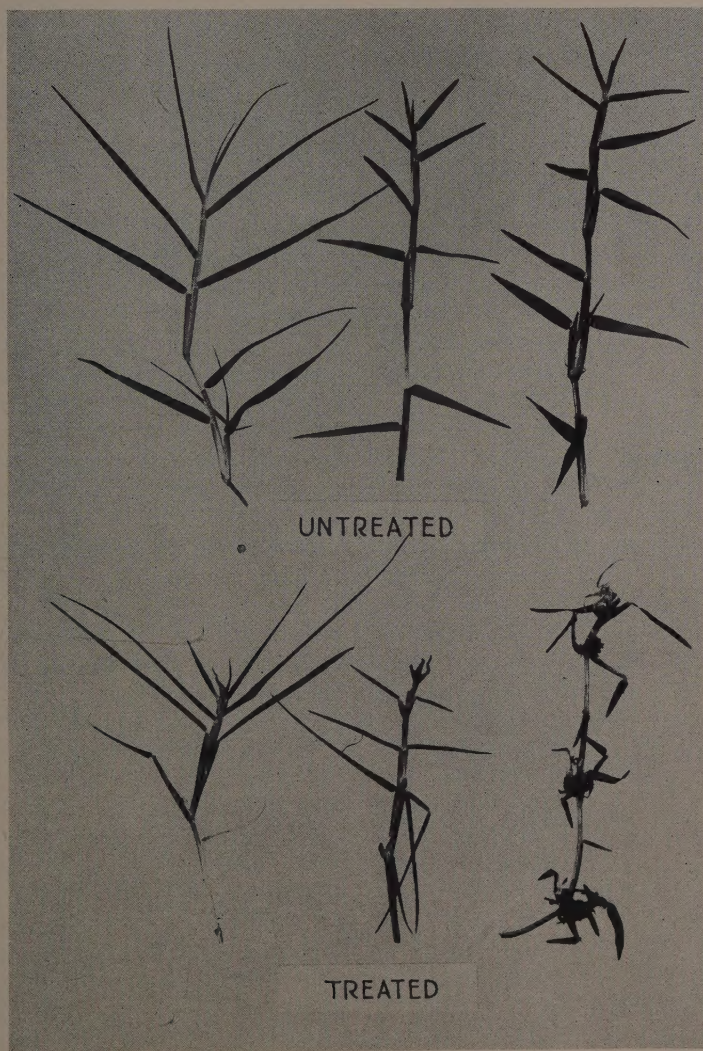


Figure 2. Effect of sodium trichloroacetate on the elongating parts of manie grass (lawn variety). Note stunted condition of growing points and buds of treated plants. Photographed two months after pot had been sprayed with a solution containing 20 pounds 50 per cent grade STCA per 100 gallons.



**TRICHLOROACETIC ACID IN DIESEL OIL** Another experiment with potted manienie (similarly organized to that above) showed that as little as 2.5 pounds of trichloroacetic acid, dissolved in sufficient Diesel oil to give a total of 100 gallons of spray solution, gave excellent control. Recovery was evident at the end of two months, but a considerable reduction was made in the size of stand due to the decomposition of dead tissues. This ability to reduce the stand by decomposition was found to be a very favorable characteristic of this type of spray and of others based upon it (to be described later), since respraying could be accomplished with gallonages of spray solution considerably under the gallonage of the initial spraying. Such decomposition of dead tissues was not as marked in cases in which aqueous solutions of the acid or of its sodium salt were used.

**TRICHLOROACETIC ACID WITH 2,4-D** The terms "activation,"

"adjuvation," and "multiple-hormone" have become fairly common in weed control literature. It has become more or less customary to explore fully any new herbicide as to possibilities of activating it, using it as an adjuvant, or, if it be a plant hormone, the employment of it with another hormone in the same formulation.

The suggestion was made by Dr. Francis E. Hance<sup>3</sup> that the inclusion of trichloroacetic acid, or some form of it, with 2,4-D would aid in increasing the effectiveness of spray solutions applied to manienie.

Results of greenhouse experiments indicate that of the three general forms of 2,4-D (ester, triethanolamine, and sodium salts) for use with TCAA in multiple-hormone sprays only the isopropyl ester gave a result that would justify its cost. For use against manienie, triethanolamine and sodium salts of 2,4-D, at least in practical amounts, may be considered virtually worthless.

#### **EMULSIONS OF TRICHLOROACETIC ACID IN DIESEL OIL, AND ISOPROPYL ESTER OF 2,4-D**

Laboratory research disclosed that an emulsion containing the two herbicides in Diesel oil could easily be prepared. When Concentrate No. 1, containing isopropyl ester of 2,4-D and the non-ionic emulsifying agent, Atlas G-1096, and trichloroacetic acid dissolved in Diesel oil were combined in the right proportions an emulsion could be prepared by the simple addition of water and stirring. Concentrate No. 1 is an 85 per cent by weight solution of isopropyl ester of 2,4-D and 15 per cent Atlas G-1096 emulsifier. The solution comprised of trichloroacetic acid dissolved in Diesel oil contains 2.5 pounds of TCAA per gal-

lon of solution. Preliminary trials of these emulsion sprays containing multiple hormones indicated that they were extremely potent against manienie.

Previous studies, concerned only with 2,4-D in its various forms, had shown that 20 to 40 pounds of 2,4-D per 100 gallons of spray solution are necessary to produce a strong wilt upon manienie and hold off recovery to more than a moderate extent for as long as two months. With previously obtained information in mind, the following formulations were prepared, based upon 100 gallons of spray solution in each case, with water being used as the diluent:

<sup>3</sup> Dr. Francis E. Hance, chemist, Experiment Station, HSPA, in charge of research on chemical aspects of weed control.



**Lbs. 2,4-D (from Concentrate No. 1) + Lbs. TCAA in Diesel oil**

25	15
20	15
15	15
15	10
10	10
10	5
7.5	5
5	5

These formulations were applied as contact sprays to manienie (lawn variety) growing in gallon cans. The 25/15, 20/15, and 15/15 formulations gave excellent con-

trol for four months and a significant reduction in stand with one application. At the conclusion of these greenhouse studies, experiments were carried to the field.

### FIELD EXPERIMENTS

F. C. Denison, Island Representative (Oahu), and Ewa Plantation Company cooperated in the installation of roadside tests at Ewa where a considerable quantity of giant manienie, growing from one to two feet high and kept in a very luxuriant state by ditch bank seepage, was available. Plots averaged 1/200 acre. Pressure knapsack sprayers, usually operated at 20 pounds per square inch and equipped with Mohawk adjustable nozzles at coarse settings, were used for making the applications. To attain optimum wetting, an average of 600 gallons per acre was found to be necessary on grass of this size. It was further em-

phasized at this stage of the research that any significant reduction in gallonage below that necessary to wet the foliage and partly wet the undergrowth resulted in poor control, if not in complete failure of what would otherwise have been a successful treatment.

The sprays employed in this experiment and the results obtained are presented in Table 1. It was emphasized by the results of this experiment that sodium trichloroacetate in aqueous solution does not give the reduction in stand accomplished by such sprays as those designated by WX-5 or WX-6.

### APPLICATION OF RESPRAYS

Experiments completed up to this point indicated that complete and permanent control with one application of any formulation thus far developed was, for all practical purposes, unsuccessful. Respraying appeared to be unavoidable if complete control and eventual eradication were to be attained. Since many of the above-mentioned formulations are comparatively expensive, it was felt that the problem centered around the need for some cheap method of causing as speedy a reduction in the size of stand as possible.

The attack upon the problem of respraying was approached in three ways: (1) respraying with initial sprays, (2) initially reducing the stand by applying a comparatively inexpensive herbicide and using the more expensive herbicides for respraying, and (3) application of a comparatively inexpensive herbicide, burning the browned grass, and then following with an application of a more expensive herbicide.

**FIRST METHOD** One block of the aforementioned roadside plots

TABLE 1—SPRAYS EMPLOYED IN EWA EXPERIMENTS

Plot No. Treatment	Oil-Soluble HSPA Activator (Penta- chlorophenol)	Pounds per 100 Gallons Spray		Diluent (to total volume of 100 gals.)	Quickness of Effect	Remarks
		2,4-D (From Conc. No. 1)	TCAA 100%	STCA 100%		
WX-1	15	—	—	—	Within 1 wk.	Respray needed at end of 3 wks.
WX-2	—	—	—	—	Within 1 wk.	Significant recovery at end of 3 wks.
WX-3	—	—	2.5	—	Within 1 wk.	Slightly better control than WX-3
WX-4	—	—	5	—	Within 1 wk.	Better control than preceding; control only 2 months
WX-5	—	—	10	—	Within 1 wk.	Good control nearly 3 mos., large reduction in stand
WX-11	—	25	15	—	Within 1 wk.	Good control nearly 3 mos., large reduction in stand
WX-6	—	17.5	15	—	Within 1 wk.	Good control nearly 3 mos., large reduction in stand
WX-7	—	14	10	—	Within 1 wk.	Significant recovery within 3 wks., respray needed after 1 mo.
WX-12	—	10	5	—	Within 1 wk.	Significant recovery within 3 wks., respray needed after 1 mo.
WX-8	—	5	5	—	Within 1 wk.	Good control nearly 3 mos., little reduction in stand
WX-9	—	—	—	20	Good burn after 7 wks.	Good control nearly 3 mos., little reduction in stand
WX-10	—	—	—	10	Beginning after 1 mo.	Good control nearly 3 mos., little reduction in stand

were given no further treatment after the initial spraying, but were kept under observation. Replicates of some of these plots were resprayed, as shown in Table 2.

**SECOND METHOD** Remaining replicates of the above plots were treated as shown in Table 3.

Area for additional plots was secured and applications made using WX-2, WX-3, and CADE at a dilution of 1 in  $1\frac{1}{3}$  plus  $1/25$  SSA. The plots receiving oil sprays WX-2 and WX-3 were resprayed at the end of six weeks with WX-2, WX-3, WX-5, WX-11, WX-6, WX-7, WX-12, and WX-9. Gallonage was reduced 33 per cent. The plots treated initially with CADE were resprayed at the end of three weeks with WX-11, WX-6, WX-7, and WX-12 with a reduction of 40 per cent in gallonage required.

While the gallonage required for the second treatment was substantially less, the results were not outstanding. The conclusion was reached that the multiple-hormone type of spray emulsion, ordinarily very effective when applied to green foliage, was not properly absorbed when applied to plants in a partly brown and dried state.

**THIRD METHOD** Additional roadside area was secured and a series of plots were treated with WX-2 and WX-3 type sprays. At the end of four weeks after application of sprays, the grass on these plots was burned off. At the end of an additional three weeks there was considerable recovery and new growth in these plots, but not enough to completely cover the plots. Resprays were made using WX-5, WX-9, WX-3, WX-2, WX-11, WX-6, WX-7, and WX-12 type sprays. The gallonage reduction was 66 per cent. Recovery and new growth were reestablished within



TABLE 2—FIRST METHOD

Plot Code No. and Type Initial Treatment	Resprayed With Type Treatment (See Table 1)	Period Since Initial Treatment	Results of Second Spraying	Per Cent Reduction in Gallage Com- pared With Initial Treatment
WX-5	WX-5	10 wks.	Unsatisfactory	50
WX-6	WX-6	10 "	Satisfactory; promising as eradicant	66
WX-7	WX-7	10 "	Satisfactory; promising as eradicant	66
WX-9	WX-9	10 "	Satisfactory	33
WX-10	WX-10	10 "	Satisfactory	33

another month, even in plots treated with such a spray as WX-11.

The conclusion was reached that trichloroacetic acid is quite inefficient as a pre-emergence herbicide. All regrowth must be allowed to be well started in order to obtain worth-while results from an application of spray containing trichloroacetic acid. This ties in with the results mentioned under the preceding heading that trichloroacetic acid is most effective when applied as a contact herbicide to green and growing grass.

**DISCUSSION** From the standpoint of **OF RESULTS** results alone, and disregarding cost, the most effective series of treatments and retreatments consists of sprayings using the multiple-hormone emulsion type of spray, such as WX-6, WX-7, or WX-11.

Since cost must be considered, the next best method is to brown the grass with an inexpensive herbicide, such as CADE, and burn off before recovery begins. Allow sufficient new growth to develop, and then begin treatments with the multiple-hormone emulsion type of spray

but at lower gallage than would have been possible without the burning-off process. If this routine is employed, care must be taken that recovery has had ample time to begin. Any rhizomes protected by soil at the time of spraying will be free to develop since the performance of trichloroacetic acid in our experiments indicates that even when used in amounts approaching 100 pounds of pure acid per acre per treatment it has little value as a soil sterilant or as a pre-emergence herbicide, even over the short period of a month.

The results of the above experiments have led to the conclusion that by the use of the better types of aforementioned sprays, preferably those of the multiple-hormone emulsion type, control and eventual elimination of manienie can be assured. Moreover, the belief is held that this can be practically accomplished by four sprayings spaced at approximately three-month intervals. Due to a reduction in stand of grass, the fourth and very probably the third spraying may be considered spot sprayings.

TABLE 3—SECOND METHOD

Plot Code No. and Type Initial Treatment	Resprayed With Type Treatment (See Table 1)	Period Since Initial Treatment	Results of Second Spraying	Per cent Reduction in Gallage Com- pared With Initial Treatment
WX-1	WX-6	6 wks.	No advantage, considering cost	33
WX-2	WX-6	6 "	No advantage, considering cost	33
WX-3	WX-6	6 "	No advantage, considering cost	33
WX-4	WX-5	9 "	No advantage, considering cost	33

## STANDARDIZATION OF EFFECTIVE SPRAYS

Two multiple-hormone emulsion type sprays, an alternate type for each, and an aqueous spray of sodium trichloroacetate have been evolved from this research. One, designated as WX-13 and containing  $22\frac{1}{2}$  pounds of 2,4-D and 15 pounds of trichloroacetic acid per 100 gallons, is simply WX-11 or WX-6 (see Table 1) slightly modified to give what we believe to be the best balance between 2,4-D and trichloroacetic acid. Its alternate is designated as WX-13S and is equal in

effectiveness, but employs sodium trichloroacetate instead of trichloroacetic acid. In like manner, WX-14 is a modification of WX-7 and contains 15 pounds of 2,4-D and 10 pounds of trichloroacetic acid per 100 gallons. WX-14S is its alternate and contains sodium trichloroacetate instead of trichloroacetic acid. The fifth formulation is WX-9, containing 20 pounds of 100 per cent sodium trichloroacetate per 100 gallons.

## RECOMMENDATIONS FOR USE OF EVOLVED FORMULATIONS

**USE WITHIN CANE LINES** The high concentration of 2,4-D within the multiple-hormone emulsion types WX-13, WX-13S, WX-14, and WX-14S very obviously make their use within cane lines unsafe. Their value in eliminating manienie from cane lines will have to be indirect, that is, by using these herbicides to eradicate manienie in sources of infestation such as field borders, roadsides, and ditch banks.

Sprays of sodium trichloroacetate at the concentration prescribed for WX-9 would also be harmful if used within cane lines. Such a spray may be readily diluted, however, to give from  $2\frac{1}{2}$  to 10 pounds of 100 per cent sodium trichloroacetate per 100 gallons of spray solution for application within cane lines. This spray solution, applied in sufficient quantity to thoroughly wet the manienie, will check the growth of the grass sufficiently to give competitive advantage to the cane.

### USE UPON FIELD BORDERS, ROADSIDES, AND DITCH BANKS

The fact that the isopropyl ester of 2,4-D is the only effective form of

2,4-D for use in multiple-hormone emulsion type sprays and the fact that this ester is undesirably volatile place a limitation upon the area in which this type of spray may be used. The use of spray nozzles which form coarse instead of atomized droplets will undoubtedly aid in extending the area permissible for this type of spray formulation.

For those areas in which this type of spray is permissible the recommendation is made that emulsion spray WX-14 or WX-14S be used for broadcast application (probably first two applications in eradication program) and WX-13 or WX-13S be used for spot spraying in areas where manienie is thin or as a follow-up for previous sprayings of WX-14 or WX-14S.

For those areas where the use of the isopropyl ester of 2,4-D is not permissible, thereby making use of WX-13, WX-13S, WX-14, or WX-14S impossible, the next best spray is formulation WX-9 (20 pounds of 100 per cent sodium trichloroacetate per 100 gallons). Most of the characteristics and results to be expected from this type spray have been pointed out previously.



## FORMULATIONS

The following embodies more specific directions for preparing most of the more effective formulations which have been mentioned. Directions for preparing various concentrates are given, followed by directions for their use in preparing spray solutions.

**TCAA-DIESEL OIL STOCK SOLUTION** Dissolve  $2\frac{1}{2}$  pounds of pure trichloroacetic acid in sufficient Diesel oil to give a total volume of one gallon when the whole is at room temperature. Very slight warming speeds the process but may be omitted. *Do not use an aromatic oil.*

**CONCENTRATE NO. 1A** Concentrate No. 1A is essentially the same as Concentrate No. 1 in one of the HSPA releases. The difference is that the proportions have been changed chiefly for the purpose of expediting calculations and measurements of volume.

*Directions (for one gallon):* Into a clean container place 9.20 pounds or 0.88 gallon of isopropyl ester of 2,4-D and add 1.02 pounds or 0.12 gallon of polyoxy ethylene hexa hydric alcohol combined with oleic acid (commercially known as Atlas G-1096). Mix and allow to stand securely covered overnight. One gallon of this concentrate contains 7.5 pounds of 2,4-D (acid equivalent).

An alternate method in case a supply of Concentrate No. 1 is on hand is to take  $\frac{1}{2}$  gallon or five pounds of Concentrate No. 1 and add 4.88 pounds or 0.468 gallon of isopropyl ester of 2,4-D and 0.27 pound or 0.032 gallon of Atlas G-1096. Mix well and allow to stand securely covered overnight.

**CONCENTRATE NO. 1B** To  $\frac{1}{2}$  gallon of Concentrate 1A, add  $\frac{1}{2}$  gallon of Diesel oil. Mix well and allow to

stand, securely covered, overnight. This concentrate contains 3.75 pounds of 2,4-D (as acid) per gallon.

**2-7-R STOCK SOLUTION** Dissolve two pounds of 2-7-R paste in water and adjust the volume to one gallon.

**STOCK SOLUTION OF STCA** Dissolve in water a quantity of sodium trichloroacetate salt to furnish an equivalent of  $2\frac{1}{2}$  pounds of pure trichloroacetic acid and adjust the volume to one gallon. The quantities of commercial grades of the salt necessary to furnish an equivalent of  $2\frac{1}{2}$  pounds of pure trichloroacetic acid are as follows:

Purity	Pounds of Salt
50%	5.68
60%	4.75
70%	4.05
80%	3.55
85%	3.34
90%	3.16
100%	2.84

**EMULSION SPRAYS WX-13 AND WX-14** These emulsion sprays should be prepared just prior to use and, if possible, utilized within two hours. In locations where irrigation water is available they may be prepared in the field.

### EMULSION SPRAY WX-13

Concentrate No. 1A...	3 gals. (22.5 lbs. 2,4-D acid)
TCAA-Diesel oil stock	6 gals. (15 lbs. 100% TCAA)
Water.....	91 gals.
Makes.....	100 gallons

### EMULSION SPRAY WX-14

Concentrate No. 1A...	2 gals. (15 lbs. 2,4-D acid)
TCAA-Diesel oil stock	4 gals. (10 lbs. 100% TCAA)
Water.....	94 gals.
Makes.....	100 gallons

## EMULSION SPRAYS WX-13S AND WX-14S

### EMULSION SPRAY WX-13S

Concentrate No. 1B... 6 gals. (22½ lbs.  
2,4-D acid)  
Water..... 88 gals.  
STCA stock solution.. 6 gals. (equiv. 15 lbs.  
100% TCAA)  
Makes.....100 gallons

### EMULSION SPRAY WX-14S

Concentrate No. 1B... 4 gals. (15 lbs. 2,4-D  
acid)  
Water..... 92 gals.  
STCA stock solution.. 4 gals. (equiv. 10 lbs.  
100% TCAA)  
Makes.....100 gallons

## STCA AQUEOUS SPRAY

STCA stock solution.. 7.05 gals. (20 lbs.  
100% STCA)  
Water..... 92.45 gals.  
2-7-R solution..... .50 gal.  
Makes.....100 gallons

*Note:* In preparing Emulsion Sprays WX-13, WX-14, WX-13S and WX-14S, and STCA Aqueous Spray, additions are to be made in the order given, with stirring.

An alternate to this procedure is to weigh out a sufficient quantity of the commercial salt equivalent to 20 pounds of pure STCA. Dissolve this in water and adjust to 99½ gallons. Then add ½ gallon of 2-7-R solution, making 100 gallons of spray. Stir after adding 2-7-R.

The formula for obtaining the desired quantity of commercial STCA for this

aqueous spray is 
$$\frac{20 \times 100}{\% \text{ purity of STCA}}$$

For example: if commercial STCA is of 60 per cent purity, then the amount of this salt required per 100 gallons is 
$$\frac{20 \times 100}{60} = 33.3 \text{ pounds 60 per cent grade STCA.}$$



# A Survey of Plantation Fertilizer Practices

By R. J. Borden<sup>1</sup>

To secure a reliable picture of the current fertilizer practices on our sugar cane lands, all plantations were asked to submit examples of the actual fertilization on representative fields of their 1949 crop. A total of 183 field fertilizer schedules were subsequently submitted by 27 plantations; 91 of these were examples from unirrigated cane and 92 were from irrigated areas.

Since the individual schedules are too extensive to reproduce, a summary has been made of their contents to show their most significant points and differences. We have also added a few comments as a sort of challenge to plantation men to critically evaluate their present fertilizer practices.

## TOTAL PLANT FOOD APPLIED

All fields received nitrogen. Acre applications ranged from 116 to 252 pounds, and averaged 189.

No phosphate was applied on 56 of the 183 fields reported. On the other fields where phosphate was used, the amounts ranged from 41 to 415 pounds of  $P_2O_5$ , with the average being 124 pounds. In the case of the lower amounts (below 50 pounds) the phosphate apparently served chiefly as the "conditioner" in the complete fertilizer mixture used; where more than 200 pounds were applied, the excess was evidently intended for future crops.

Potash applications, where used at all (on 154 fields), were between 100 and 344

pounds of  $K_2O$  per acre, averaging 204 pounds.

These average phosphate and potash applications, and their deviations as shown on different field schedules, appear to be well founded and rational. The nitrogen applications, however, appear somewhat high, especially when they are above 200 pounds per acre. Grade A field tests have seldom shown proved gains in sugar for amounts of nitrogen above 175 to 200 pounds per acre even when cane yields were well over 100 tons. Hence, one may question the use of more than this nitrogen for those fields represented by 68 of the examples included in this summary.

## METHODS OF APPLICATION

All plantations applied some fertilizer by hand, and an average of three applications were made by this method, on the cane row.

Only 13 of the 27 plantations' schedules showed the use of machines for

fertilizer application.

Of the 16 plantations which have water for irrigation, only eight applied some of their nitrogen in the irrigation water; four of these made as many as three separate applications in water.

<sup>1</sup> R. J. Borden is statistician, Experiment Station, HSPA.

In this "mechanical age" one must challenge the actual need for hand application of fertilizer. Both the merits and demerits of changes that might have to be made in the fertilizer practice to make it possible to use fertilizer machines need

careful consideration. Moreover, the divided opinion about the efficiency of water applications makes it apparent that the real facts have not been well established.

NUMBER OF APPLICATIONS

Most of the unirrigated fields received their total fertilizer in three applications, whereas four applications were more common on the irrigated fields. (Figure 1). Single applications were exceptionally rare (only on two unirrigated fields.)

The number of applications appears

excessive, and fewer applications should be possible without loss of effectiveness. There is little experimental evidence to support the very common practice of splitting the total amount of fertilizer to be applied into several applications. On the other hand, economies are possible from fewer applications.

TIME TO COMPLETE FERTILIZATION

From the data studied, the trend shows slightly earlier fertilization on the unirrigated fields, (Figure 2) and, in general, a completion of all fertilization within nine months after starting the crops. On the irrigated fields there were about as many fields where fertilization

was completed within five months as in 11 months.

Is delayed fertilization on a well established crop essential? Experimental evidence showing the relative effects from completing the fertilization early as compared with saving part of the total

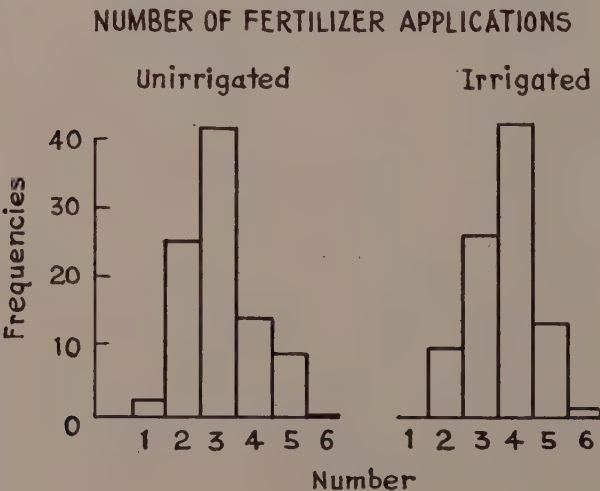


Figure 1.



## TIME TO COMPLETE FERTILIZATION



Figure 2.

amount for a late application (at 10 to 12 months) is still somewhat inadequate. A differential in this respect might well

be tied in with the specific age and season relationship of the crop concerned.

## TOTAL POUNDS OF NITROGEN APPLIED

Applications of nitrogen were somewhat higher for cane grown under irrigation. (Figure 3). The greatest frequencies, however, are found in the 180 to 199-pound groups from both irrigated and unirrigated fields. Not much cane appears to be grown with less than 160

pounds of nitrogen per acre, so it is doubtful that there is much nitrogen-deficient cane being grown. On the other hand, there are instances where the amounts applied seem excessive, and not supported by valid experimental findings.

## POUNDS OF NITROGEN IN FIRST APPLICATION

The irrigated fields get smaller amounts of nitrogen in their initial applications, and  $\frac{2}{3}$  of the field schedules show the amount of this first application at less than 60 pounds per acre. (Figure 4). Amounts in excess of 60 pounds are more common on the unirrigated lands.

There is little experimental evidence to show the maximum amount of nitrogen which can be used most efficiently as the crop gets underway. The question is apparently tied in with the number of applications it is desired to make on the crop.

## PHOSPHATE PLACEMENT

Nearly  $\frac{3}{4}$  of the 51 plant fields which were given phosphates received this material as a surface soil application after the crop was up. (Figure 5). On 76 ratoon fields phosphate was applied on the surface soil of 37 unirrigated and of 21 irrigated fields. Less than  $\frac{1}{4}$  of these ratoons

received sub-surface applications.

In spite of the fact that sub-surface applications of phosphates are known to be more available (positionally) than surface applications, the trend shown in this summary reveals widespread disregard of this preferred placement.

## TOTAL POUNDS OF NITROGEN APPLIED



Figure 3.

## NUMBER OF APPLICATIONS CARRYING POTASH

Almost all unirrigated fields received some potash, and an average of 230 pounds per acre was applied, about equally in one, two, and three applications. (Figure 6). On the other hand, the

average application of 170 pounds used on irrigated fields was most often given in a single dose.

Opinions are prevalent but facts are scanty about the need for splitting the

## POUNDS OF NITROGEN IN FIRST APPLICATION

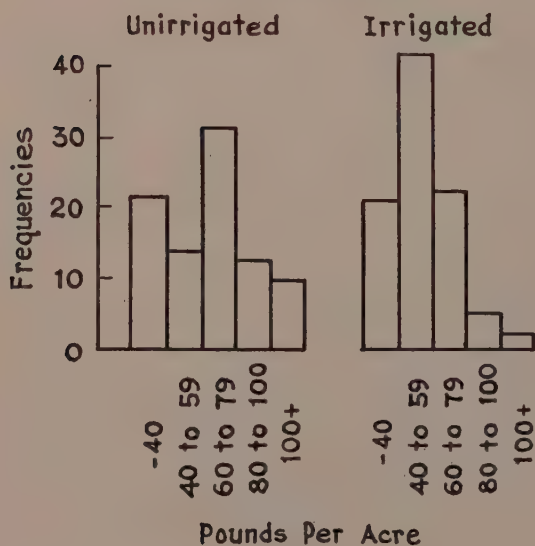
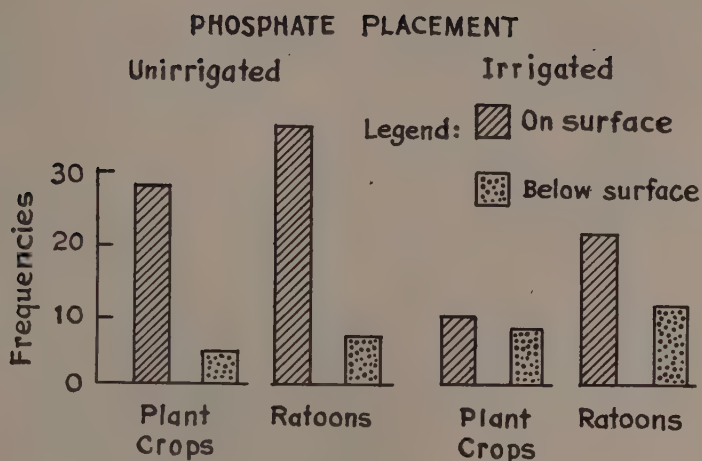


Figure 4.

Figure 5.



total potash fertilization into several applications. As is the case with soluble nitrogen, it is apparently the fear of losses by leaching that dictates these

split applications of potash. Evidence of such losses in fields with growing crops of cane has yet to be reliably established.

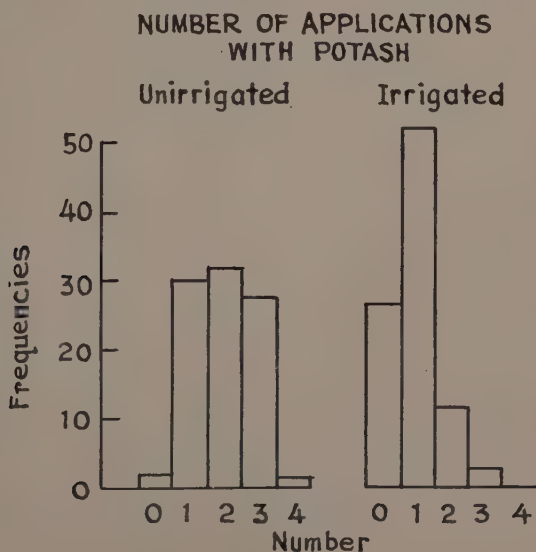
#### FIELD DIFFERENTIATION

One of the most significant observations from this study of the different fertilizer schedules leads to the conclusion that there was *no obvious differentiation* for separate fields within the plantation as follows: (a) in nitrogen fertilization on

14 plantations; (b) in phosphate fertilization on 12 plantations; and (c) in potash fertilization on 13 plantations.

It is difficult to believe that this lack of differential field fertilization can be left unchallenged. Soils differ, sunlight

Figure 6.





differs, actual sugar yields differ, etc. between plantation fields, and so it is a bit unreasonable to expect that any one

standard fertilizer and policy can best serve the wide differences known to exist between fields on any one plantation.

# Spraying Weeds With Straight CADE

By Harold H. Hall<sup>1</sup>

## SUMMARY

We are interested in a chemical weeding practice that does not hinder the continuous growth of cane. Accordingly, we have adopted the application of straight (undiluted) CADE as standard practice. The advantages of uniformly applying this herbicide at low gallonage are:

- It is a one-package spray which may be applied as it comes from the homogenizer. Normal field operations are not held up because of spraying. Spraying is effective either just before or just after a scheduled irrigation.
- The non-productive walking time of spray gang personnel is reduced; only five knapsack fillings are required per acre as against 20 fillings under the former system of applying CADE diluted 1 in 8.
- Due to lower output, maximum knapsack pressure is maintained at a minimum of physical exertion.
- The labor saving per acre amounts to \$2.62; a material saving of 38 cents per acre is also realized.
- The supply truck operation is reduced to one trip per day, and since the spray is concentrated and is applied at low gallonage, large truck units are not needed.
- The stepped-up man day performance obtained, using the same number of sprayers, results in a repeat cycle which starts sooner.
- The outlay for additional spray equipment (aluminum boom, strainers, nozzles) is small, the extra cost per sprayer being \$2.00.
- Straight CADE is non-injurious to the spray men, and activator fumes are reduced to a minimum. This material is noncorrosive on spray equipment.
- The milky tracer effect of straight CADE results in better coverage and less missing.
- The employment of a narrow boom enables workers to keep this concentrated herbicide off cane stubble and thus assures continuous growth of the cane.
- Good man day performance is achieved because knapsacks are efficiently filled from a supply of previously strained material which is delivered directly to the

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<sup>1</sup> Harold H. Hall is agriculturist at Pioneer Mill Company Ltd.

area being sprayed. Also, weeds are sprayed when in the two-leaf stage, using a two-nozzle boom and efficient nozzles which increases the speed of application and gives good coverage.



Figure 1. Showing weed types encountered; wild zinnia, fox-tail, Koa haole, purslane (pig weed), jungle rice, ilima, rattle pod, and wire grass.

Figure 2. Weeds and grass just after spraying with straight CADE. Note white coating on leaves.





- Straight CADE is potent; it is a balanced spray which kills the weeds uniformly and fast (Figs. 1-4). In short, it is "death on weeds."



Figure 3. Showing the effect on weeds in Figure 1, 24 hours after spraying with straight CADE.

Figure 4. Purslane 24 hours after spraying.



## INTRODUCTION

Spraying weeds with straight CADE involves contact spraying in the two-leaf stage, the process being slowed down somewhat to obtain a definite weed kill. This eliminates frequent repeat sprayings, reduces the amount of hand hoeing required, and results in heavy stalk populated fields being closed in early and cheaply.

Because of a material shortage brought about by the recent shipping strike, it became necessary to develop a new spray formula designed to use less activator<sup>2</sup> but which would permit continued spray-

ing in spite of the dwindling supply of this chemical.

One of the many preliminary tests made showed that a good, quick kill resulted when weeds were sprayed with straight CADE applied by knapsack. In order to bring the cost of material applied per acre within an economical range, a hollow-cone-type nozzle was altered to meet this requirement. The combination of a good, low-gallonage nozzle and a concentrated spray, it was felt, would result in a positive weed kill with less labor per acre and using a smaller amount of a cheaper weed spray.

## EXPERIMENTAL

To obtain the gallonage output desired (eight gallons per acre per nozzle), a No. 1.27 Spraying Systems Company tee jet tip was altered so that at maximum knapsack pressure the output per nozzle was increased to 0.067 gallon per minute. This nozzle emits a hollow-cone spray pattern (Fig. 5).

Straight CADE was applied to half the cane line at a time, using a two-nozzle aluminum alloy spray boom with a line strainer and nozzles attached to a four-gallon Champion knapsack sprayer. Thirty minutes were required to apply a knapsack of four gallons of straight CADE (0.133 gallon per minute) to an area of  $\frac{1}{4}$  acre. (Repeat tests showed that two hours were needed to spray one acre, using 16 gallons of straight CADE.)

The even, milky spray pattern was well distributed on the entire weed leaf surface. A few minutes after the application, it was noted that the spray had uniformly penetrated the leaf tissue, causing it first to become translucent and then flaccid as the activator ruptured



Figure 5. A close-up of the spray boom showing hollow-coned spray pattern of straight CADE.

<sup>2</sup> HSPA Activator, sodium pentachlorophenate.

the cellular tissue. This was evident on the waxy- as well as on the hairy-leaved weeds. Within a few hours the sprayed weeds died and blackened.

The initial per acre performance and

cost figures on straight CADE (first spraying on small weeds) indicated a total of three acres sprayed per man day at a total cost of \$4.18, including \$2.31 for labor and \$1.87 for material.

## DISCUSSION

In view of the potential savings realized in both labor and material as a result of these experiments, and because of our varied field conditions (surface rock, steep slopes, and deep furrows) and the need to keep expensive hand hoeing at a minimum, it was felt that the use of straight CADE might offer still greater rewards if the system were fully exploited. Accordingly, the decision was reached to completely equip a regular spray gang with new booms and nozzles for testing the system on a field scale. A more efficient system for filling knapsacks and modification of the supply routine were included in the program.

Twelve regular spray men were completely equipped with the new booms, nozzles, and knapsacks (Fig. 6). Work began on September 16 and ended a month later, the men being paid at an hourly rate of  $86\frac{1}{2}$  cents.

The spray trailer was equipped with 100-mesh spray strainers and a pumping system which enables the truck driver to dispense straight CADE by hose and shut-off nozzle into each knapsack without removing the knapsack from the sprayer's back (Fig. 7). Only 30 seconds are required to fill a knapsack and, in addition, spillage and time lost at the filling station are cut to a minimum. The truck drivers report to work with a 600-gallon tank load of straight CADE taken on the afternoon before, and a 375-gallon dispensing trailer is hauled behind the truck and filled whenever necessary. The truck driver remains with the gang all

day, repairing spray equipment between knapsack fillings.

At the end of the trial period of one month, and after many of the problems and rates of pay had been worked out, this same group started to spray on a contract rate of pay which netted the workers better earnings through more efficient conditions. This resulted in decreased operating costs.

A comparison of per acre performance figures and cost data for straight CADE



Figure 6. The author demonstrating knapsack spraying equipment currently in use.



TABLE 1

Per application	Straight CADE	Standard CADE 1 in 8	Per acre saving
Acres sprayed per man day.....	2.6	1.3	1.3
Labor cost per acre.....	\$3.02	\$5.64	\$2.62
Material cost per acre.....	\$2.46	\$2.84	\$0.38
Total cost per acre.....	\$5.48	\$8.48	\$3.00
Pounds of activator per acre.....	1.47	6.07	4.60

by this test gang vs. the former standard practice of spraying CADE diluted 1 in 8 is included in Table 1.

As a result of these experimental studies, all of our spray gangs have been reorganized to spray straight CADE. At present our four knapsack spray gangs comprise a total of 44 men. Each has a luna and an operator for each supply truck-trailer. The 600-gallon supply truck and 375-gallon dispensing trailer travel on field zone roads which are spaced about 500 feet apart. Each trailer is equipped with a transfer pump and a dispensing nozzle. Knapsacks are filled at the roadside without being removed from the backs of the spray operators. The spray men travel 250 feet down the cane row and spray half the line. When they reach the irrigation pipe line, they turn and spray the other half of the same line as they walk toward the road. This prevents the spray from coming in contact with the cane and, therefore, assures its continuous growth.

The first spraying is purposely delayed to insure weed seed germination, being normally applied when the soil has dried out after the second round of irrigation water. The second spraying occurs about 21 days later, when a new crop of two-leaf weeds appears. Two or three re-



Figure 7. Dispensing straight CADE directly into a knapsack at the roadside filling station.

peat sprayings (made under conditions similar to those of the second spraying) follow until the cane closes in. For crops started during the warm months, four sprayings are required to close in the crop; for crops started during the cold months, five sprayings are needed before the cane closes in.

The total labor-material cost of applying straight CADE (homogenized) at 21 gallons per acre is \$5.48.

#### ACKNOWLEDGMENTS

The writer wishes to thank Dr. Francis E. Hance for his keen interest and inspiring suggestions in regard to furtherance of the research along the lines indicated in this paper.

Much credit is due to various staff members of Pioneer Mill Company Ltd. for helpful suggestions.

# Notes on the Life History of the Sugar Cane Leaf Hopper

By C. E. Pemberton<sup>1</sup>

The sugar cane leaf hopper, *Perkinsiella saccharicida* Kirk, (Figure 1 and 2) which invaded Hawaii from Australia over 50 years ago and gained great notoriety because of its threat to the very existence of the sugar industry, has received little notice during the past 25 years because of the intense control effected upon it by imported natural enemies. (Figure 3) As it is a carrier of the dreaded Fiji disease of sugar cane, providing it has previously fed on diseased cane, the fear that the disease may ultimately gain a foothold in Hawaii via the expanding air traffic between Hawaii and regions where the disease is known, has revived an interest in this insect.

Fortunately, Fiji disease has not yet reached Hawaii; but it does occur in Australia, New Britain, New Guinea, Solomon Islands, Bismarck Archipelago, Philippine Islands, Fiji and Samoa. In point of time some of these countries have been brought close to Hawaii in recent years through the modern development of trans-oceanic air traffic.

Even with the ever increasing application of quarantine measures to planes arriving in Hawaii from overseas, the danger of disease-infected leaf hoppers or canes reaching Hawaii on such carriers cannot be dismissed as impossible. This danger applies particularly to planes from Fiji where sugar cane infested with leaf hoppers and infected with Fiji disease is now growing within a few hundred yards of the Fiji airport from which planes depart for Hawaii at regular intervals.

In view of the growing fear that Fiji disease may ultimately invade Hawaii, the Samoan substation of the Experiment Station was established in 1946 to test the resistance to Fiji disease of cane varieties propagated in Hawaii and to enable Station pathologists to study the disease, which has been known in Samoa for many years.

Since our leaf hopper and two other closely allied species with similar habits are the only known vectors of the disease, an understanding of their life habits should prove useful to pathologists engaged in a study of this malady. There is a paucity of published information on the habits of our sugar cane leaf hopper, though much has been written about it from other viewpoints. To meet this need the major features in the life history of the leaf hopper in Hawaii are here summarized from our field and laboratory notes.

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<sup>1</sup> C. E. Pemberton is entomologist with Experiment Station, HSPA.

## LOCATION OF EGG

Eggs are imbedded somewhat obliquely in the cane tissue in punctures or slits made by the sharp ovipositor of the female. They are placed in the upper and lower surface of the leaf midribs, in soft internodes of the stalk not covered by leaf sheaths and occasionally in the sheaths. Although not commonly found there, eggs are sometimes inserted in the stalks of various grasses growing in infested cane fields.

Each egg puncture is usually covered with a slight deposit of a white waxy

substance. Within a few days the puncture becomes conspicuous as a red or wine colored spot, caused by the development in the surrounding tissues of the red rot fungus *Phyalospora tucumanensis* Speg. When punctures are numerous in the midrib the spots are fused to give much of the midrib a reddish color.

Usually four to six eggs are placed in each puncture. A count once made of 2,939 punctures gave an average of 4.9 eggs per puncture.

## DURATION OF EGG STAGE

At mean temperatures ranging from 64.6 to 71.8° F., the maximum incubation period on 2,568 eggs was found to be 41 days and the minimum 13 days; the period varying with the mean temperatures prevailing during each test.

There is a considerable range in the incubation period in any given lot of eggs laid on the same day and exposed

to the same temperatures. For instance, of 576 eggs deposited on the same day, 23 hatched on the 15th day and the rest continued hatching for the ensuing 16 days with the majority on the 17th and 18th days. In another record on 1210 eggs all hatched after 13 to 18 days of incubation, with the majority of the young emerging on the 15th day.

## DURATION OF NYMPHAL STAGE

The nymphal stage of the leaf hopper is that period in its life from the time it hatches from the egg until it becomes an adult. It sheds its skin five times during this growth period.

With mean temperatures lying between 64.6 and 66.2° F., 1861 leaf hoppers under investigation passed through their nymphal stages in periods varying between 24 and 69 days. The average for the higher mean temperature was 28.5 days and at the lower temperature 56.6 days, indicating a rather strong reaction to even moderate changes in tempera-



Figure 1. Dorsal view of sugar cane leaf hopper. Enlarged 11 times. (After Kirkaldy, HSPA Ent. Bull. 1, Part 9, 1906.)





Figure 2. Lateral view of sugar cane leaf hopper. Enlarged 18 times.

ture. These data were obtained at Mountain View, Hawaii, where temperatures are considerably lower than in Honolulu.

In any given lot of nymphs, all hatching on the same day, there is some variation in the time required for completion of their development. For example, of 89 hoppers hatching on January 8, 1920, at Mountain View and daily fed soft cane stalks, all matured to adults between 52 and 61 days.

Dr. O. H. Swezey, former head of our department, determined the duration of the nymphal stage of a large number of individuals in Honolulu over a period of 10 months beginning in January, 1918. The mean temperature ranged from 70.3 to 78.4° F., during the period of study. He found the nymphal stage varied from an average of 40 days during the coolest months to an average of 23 days during the summer.

#### DURATION OF ADULT LIFE

At mean temperatures lying between 74.0 and 75.4° F., 59 freshly matured adults held in glass jars in a screened insectary in Honolulu and daily fed fresh leaves and soft stalks of sugar cane, lived from 20 to a maximum of 74 days. Forty-eight lived over one month, eight over 1½ months and three lived over two months.

Without food, leaf hoppers are very short lived. Of 220 adults confined without food, at a mean temperature of 66.5° F., one lived for 78 hours. All others died in from 24 to 56 hours. As the temperature is raised the survival period of unfed hoppers will be progressively shortened.



### AGE WHEN EGG-LAYING BEGINS

At a mean temperature of 71.6° F., 140 females mated and began ovipositing from 11 to 15 days after moulting to the adult stage. Other females held at a mean temperature of 63.2° F., began egg laying when 18 days old. Eggs were mostly deposited during the daylight hours.

### DAILY RATE OF OVIPOSITION

Daily oviposition records taken on 66 females gave an average per female of 105 eggs deposited over an average period of 30 days. A few eggs are usually deposited daily, sometimes as few as two but occasionally a dozen or more.

The greatest number laid was by an individual that deposited 166 eggs over a period of 55 days. Under field conditions this number is probably exceeded by exceptional individuals.

### LENGTH OF LIFE CYCLE

The life cycle, as here considered, may be described as that period of time elapsing between the laying of an egg and its ultimate development into a sexually mature adult.

From the data above it is shown that the life cycle may vary in Hawaii from about 47 to 128 days depending upon the mean temperatures prevailing during growth from egg to adult. As the temperature drops the cycle is coincidentally prolonged.

Under Samoan conditions with uniformly warm weather throughout the year, the cycle can be expected to average close to the minimum of 47 days occurring in lowland Hawaii during the summer.

Figure 3. Sugar cane leaf hoppers on stalk of cane. Natural size.

## FLIGHT OR MIGRATION OF ADULT

On warm, quiet evenings adults of both sexes tend to move out to the ends of the cane leaves, take off and fly in rather straight lines for varying distances. Some have been observed to fly for at least 100 yards before alighting and seldom more than 15 feet above ground. The flight is slow, measured individuals having been found to fly at a rate of about four miles per hour. No flying has been observed during either rainy or windy weather or at tempera-

tures below 65° F. Flights begin shortly after sunset and no flying occurs during daylight hours unless the hoppers are disturbed and then they move only a few yards at the most.

During the early years of hopper abundance in Hawaii on favorable evenings the air would be thick with flying individuals moving in all directions. Such movement accounts for the rapid infestation of young fields of cane.

## MOVEMENT OF NYMPHS

Though Fiji disease does not occur in Hawaii, experimental evidence in other countries indicates that only the nymphal stages of the leaf hopper are able to transmit the disease.

Unless disturbed, the nymphs are not likely to leave the particular cane stools on which they were born, since they cannot fly. On smooth surfaces they can crawl rapidly and are able to jump several inches in a single hop. Their jumping ability, which is likewise shared by the adult, gives them the name "leaf hopper." However, their capacity to crawl and jump is so limited it is improbable that nymphs ever move more than a few yards away from the cane on which they hatch.

Gusts of wind, the lashing of the leaves or other disturbance may cause them to fall or jump to the ground. By crawling or jumping they can return to the same or adjacent cane in a few hours; but there is no migration by such a means. Many experiments have been conducted to verify this habit.

Unless proof is finally established that flying adults can transmit Fiji disease, its extensive spread in cane fields is probably accomplished through the planting of infected cuttings or to a lesser extent by the occasional and accidental transport of infected nymphs with cultivating machinery and other equipment operating within the fields.

## LEAF HOPPER ABUNDANCE

At present the leaf hopper is so well controlled in Hawaii by imported natural enemies that it is difficult to find more than one or two hoppers per stool of cane in most fields. Prior to the introduction of parasites and predators it was common to find many hundreds of leaf hoppers per stool.

As an instance of the enormous numbers of this pest that once prevailed in some of the Hawaiian cane fields, our

notes record the finding of an average of 453 eggs in each of the upper leaves of average cane stalks in a field of Olaa Sugar Company. Sugar losses were naturally heavy as a result of such infestations. At such times a low buzzing, like the sound of a distant waterfall, was continuously heard in the fields, particularly on quiet evenings. This low, rasping note is made by the males and is caused by the rapid, lateral vibration



of the abdomen against the wings.

Should circumstances arise resulting in the suppression of the natural enemies of the leaf hopper in Hawaii, it would rapidly return to its original injurious status. Its potentialities for increase remain unchanged. It is now held under a natural blanket of control from which

there is no escape. Should this blanket be lifted or greatly disturbed the leaf hopper will quickly manifest itself in countless numbers in our cane fields. In view of the number of years that its parasites have kept the leaf hopper under control, however, we do not anticipate such a catastrophe.









